LTE/NR Architecture & principles

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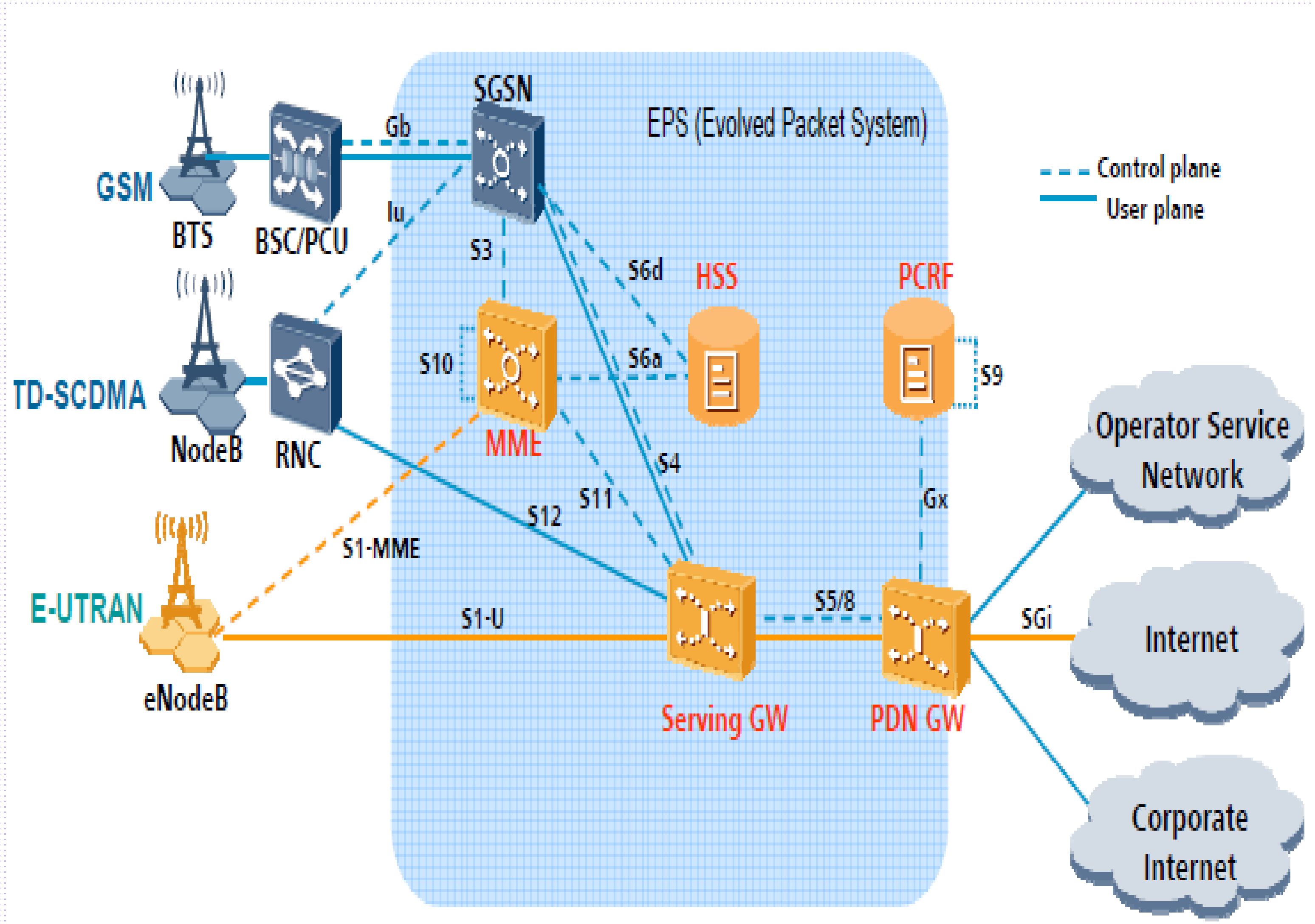
Contents

LTE/GSM/UMTS architecture



- Most functions of the RNC/BSC are deployed on the eNodeB, and some functions are deployed on the MME. This feature reduces system latency and prevents single points of failure.
- The signaling plane is separated from the user plane, and the proper division of labor leads to higher work efficiency.
- The CS domain of the traditional network is removed from the PS domain. The all-IP networking architecture is more flexible and simplified.

Functions of LTE NEs

Functions of the e-NodeB

- The radio resource management function ,implements radio bearer control,radio admission control, and connection mobility control, and implements dynamic resource allocation (scheduling) on the UE in the uplink and downlink
- Compression and encryption of IP headers of user data streams
- MME selection when the UE is attached
- Implements routing for S-GW user-plane data
- performing scheduling and transmission of paging information and broadcast information initiated by the MME
- Performs measurement and measurement reports related to mobility configuration and scheduling

Functions of the SGW

- Packet data routing and forwarding; Mobility and handover support; Lawful interception; charging.

Functions of the MME

- Encryption and integrity protection of non-access stratum (NAS) signaling;
- Access stratum (AS) access layer security control and mobility control in idle state;
- Supports paging, handover, roaming, and authentication

Functions of the PGW

- Packet data filtering; IP address allocation for the UE; Uplink and downlink charging and rate limiting.

Contents

Duplex mode, frequency band, and bandwidth supported by LTE

- Three duplex modes are supported
  - FDD,TDD &half-duplex FDD
- Supports multiple frequency bands
  - FDD system from 700 MHz to2.6GHz
  - TDD system ranges from 1900 MHz to 2620 MH.
- Supports multiple bandwidth configurations.
  - 1.4MHz, 3MHz, 5MHz, 10MHz, 15MHz, 20MHz

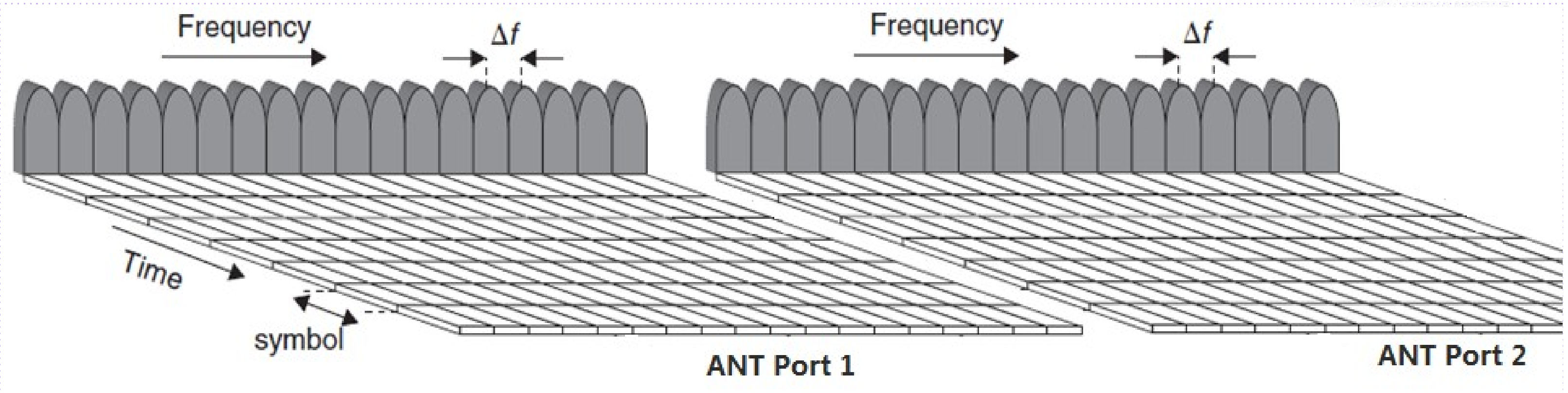
3GPP-band(nr&lte &umts&gsm)

36.104 protocol

E-UTRA Operating Band	Uplink (UL) operating band BS receive UE transmit F_{UL_low} – F_{UL_high}			Downlink (DL) operating band BS transmit UE receive F_{DL_low} – F_{DL_high}			Duplex Mode
1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
5	824 MHz	–	849 MHz	869 MHz	–	894MHz	FDD
6[1]	830 MHz	–	840 MHz	875 MHz	–	885 MHz	FDD
7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD
8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	FDD
9	1749.9 MHz	–	1784.9 MHz	1844.9 MHz	–	1879.9 MHz	FDD
10	1710 MHz	–	1770 MHz	2110 MHz	–	2170 MHz	FDD
11	1427.9 MHz	–	1447.9 MHz	1475.9 MHz	–	1495.9 MHz	FDD
12	699 MHz	–	716 MHz	729 MHz	–	746 MHz	FDD
13	777 MHz	–	787 MHz	746 MHz	–	756 MHz	FDD
14	788 MHz	–	798 MHz	758 MHz	–	768 MHz	FDD
15	Reserved			Reserved			FDD
16	Reserved			Reserved			FDD
17	704 MHz	–	716 MHz	734 MHz	–	746 MHz	FDD
18	815 MHz	–	830 MHz	860 MHz	–	875 MHz	FDD
19	830 MHz	–	845 MHz	875 MHz	–	890 MHz	FDD
20	832 MHz	–	862 MHz	791 MHz	–	821 MHz	FDD
21	1447.9 MHz	–	1462.9 MHz	1495.9 MHz	–	1510.9 MHz	FDD
22	3410 MHz	–	3490 MHz	3510 MHz	–	3590 MHz	FDD
23	2000 MHz	–	2020 MHz	2180 MHz	–	2200 MHz	FDD
24	1626.5 MHz	–	1660.5 MHz	1525 MHz	–	1559 MHz	FDD
25	1850 MHz	–	1915 MHz	1930 MHz	–	1995 MHz	FDD
...							
33	1900 MHz	–	1920 MHz	1900 MHz	–	1920 MHz	TDD
34	2010 MHz	–	2025 MHz	2010 MHz	–	2025 MHz	TDD
35	1850 MHz	–	1910 MHz	1850 MHz	–	1910 MHz	TDD
36	1930 MHz	–	1990 MHz	1930 MHz	–	1990 MHz	TDD
37	1910 MHz	–	1930 MHz	1910 MHz	–	1930 MHz	TDD
38	2570 MHz	–	2620 MHz	2570 MHz	–	2620 MHz	TDD
39	1880 MHz	–	1920 MHz	1880 MHz	–	1920 MHz	TDD
40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD
41	2496 MHz		2690 MHz	2496 MHz		2690 MHz	TDD
42	3400 MHz	–	3600 MHz	3400 MHz	–	3600 MHz	TDD
43	3600 MHz	–	3800 MHz	3600 MHz	–	3800 MHz	TDD

Note 1: Band 6 is not applicable

TD-LTE frame structure——frequceny resource



bandwidth（MHz）		1.4	3	5	10	15	20
Number of subcarriers	**conventional carrier**	72	180	300	600	900	1200
	Multicast carrier	144	360	600	1200	1800	2400

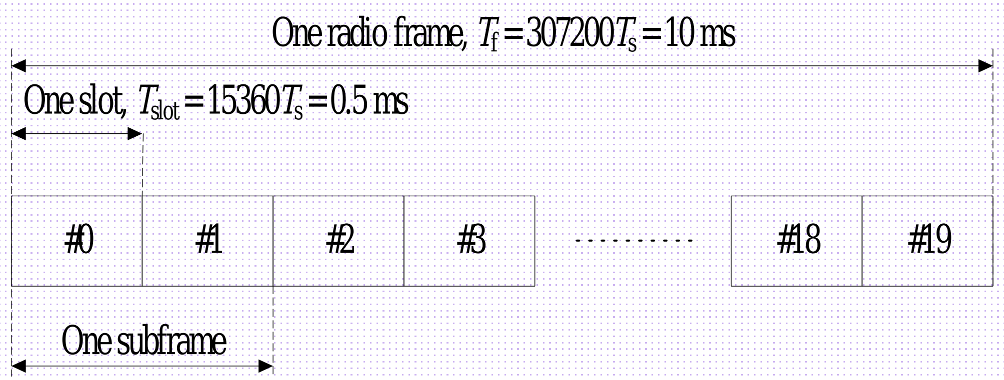
LTE uses orthogonal subcarriers to distinguish resources in the frequency domain. The subcarrier spacing is 15 kHz or 7.5 kHz.

conventional carrier

Multicast carrier

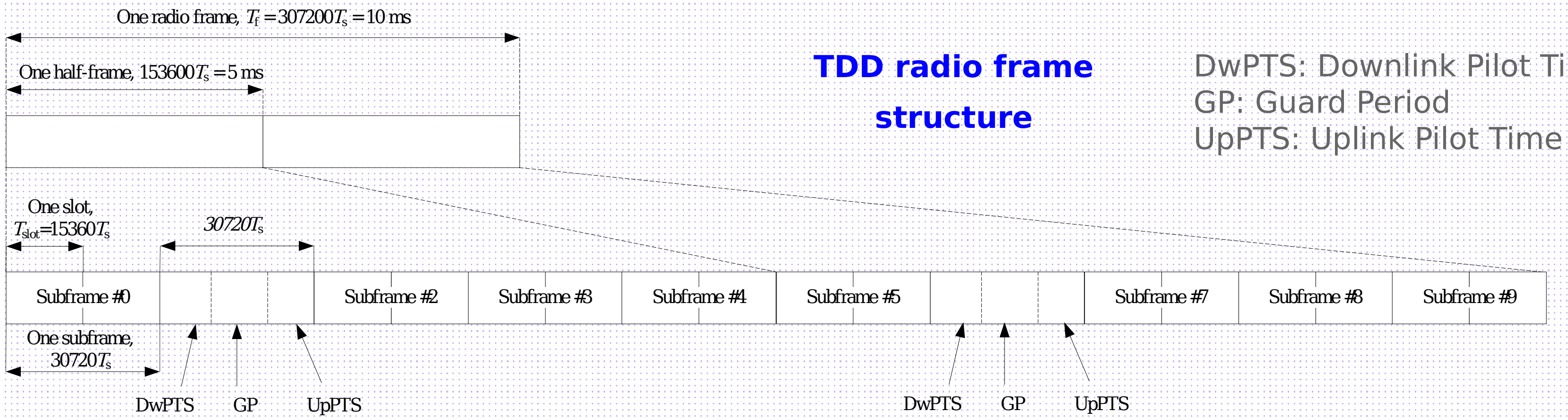
Radio frame structure

- **Both LTE FDD and LTE TDD use the OFDM technology.**
- **The subcarrier spacing is Δf=15kHz**
- **LTE supports two radio frame structures**
  - Type 1, applicable to frequency division duplex FDD
  - Type 2, applicable to time division duplex TDD
- **1 radio frame = 10ms**
- **1 subframe= 1ms**
- **1 slot = 0.5 ms**
- **1 radio frame = 10 subframes = 20 slots**



FDD radio frame structure

The number of OFDM symbols in each slot depends on the CP type.

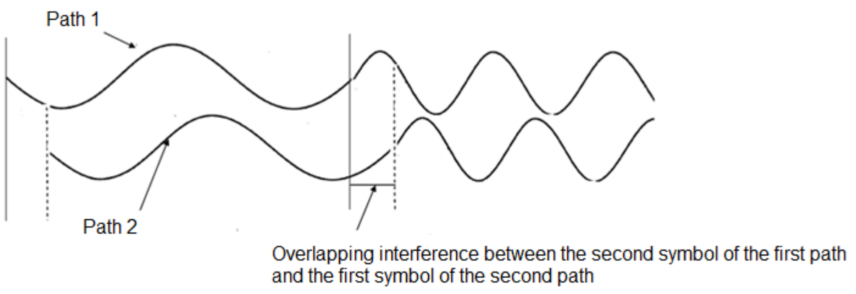


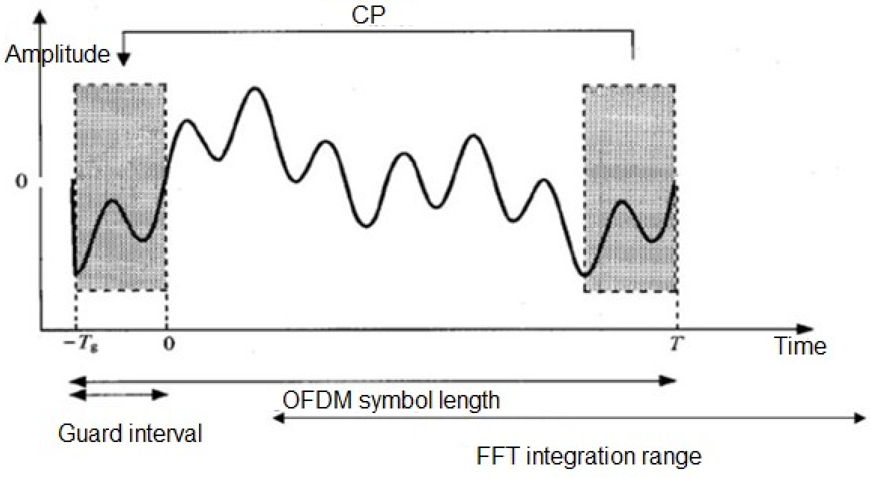
TDD radio frame structure

DwPTS: Downlink Pilot Time Slot
GP: Guard Period
UpPTS: Uplink Pilot Time Slot

CP(cyclic prefix): Background and Principles

- **Multipath latency extension**
  - The width extension of the received signal pulse caused by multipath is the difference between the maximum transmission latency and the minimum transmission latency. The latency extension varies with the environment, terrain, and clutter, and does not have an absolute mapping relationship with the cell radius.
- **Impact**
  - Inter-Symbol Interference (ISI) is generated, which severely affects the transmission quality of digital signals.
  - Inter-Channel Interference (ICI) is generated. The orthogonality of the subcarriers in the OFDM system is damaged, which affects the demodulation on the receive side.
- **Solution: CP for reduced ISI and ICI**
  - Guard intervals reduce ISI. A guard interval is inserted between OFDM symbols, where the length (Tg) of the guard interval is generally greater than the maximum latency extension over the radio channel.
  - CP is inserted in the guard interval to reduce ICI. Replicating a sampling point following each OFDM symbol to the front of the OFDM symbol. This ensures that the number of waveform periods included in a latency copy of the OFDM symbol is an integer in an FFT period, which guarantees subcarrier orthogonality.





CPs between OFDM symbols resolve ISI and ICI caused by multipath propagation.

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TDD Uplink-downlink subframe configuration and special slot assignment

DL/ULSubframe Allocation Options

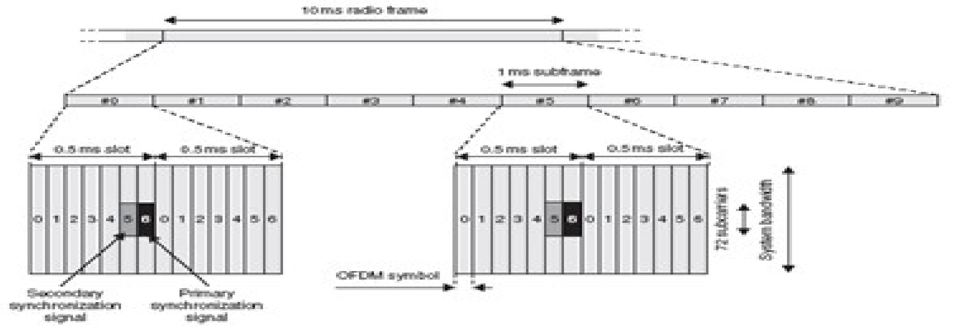
DL-UL Configuration	Switch-point periodicity	Subframe number 0	1	2	3	4	5	6	7	8	9
0	5 ms	D	S	U	U	U	D	S	U	U	U
1	5 ms	D	S	U	U	D	D	S	U	U	D
2	5 ms	D	S	U	D	D	D	S	U	D	D
3	10 ms	D	S	U	U	U	D	D	D	D	D
4	10 ms	D	S	U	U	D	D	D	D	D	D
5	10 ms	D	S	U	D	D	D	D	D	D	D
6	5 ms	D	S	U	U	U	D	S	U	U	D

D: Downlink subframe
U: Uplink subframe
S: Special subframe

- The LTE-TDD frame structure features uplink-downlink conversion.
- subframe for uplink-downlink conversion is called a special subframe
  - including DwPTS , GP, UpPTS
- The uplink-downlink slot assignment and special subframe configuration need to be planned; UpPTS mainly bear RACH and Sounding RS

Special subframe allocation options

□□□□□□	Normal CP DwPTS	Normal CP GP	Normal CP UpPTS	Extended CP DwPTS	Extended CP GP	Extended CP UpPTS
0	3	10	1	3	8	1
1	9	4	1	8	3	1
2	10	3	1	9	2	1
3	11	2	1	10	1	1
4	12	1	1	3	7	2
5	3	9	2	8	2	2
6	9	3	2	9	1	2
7	10	2	2	-	-	-
8	11	1	2	-	-	-



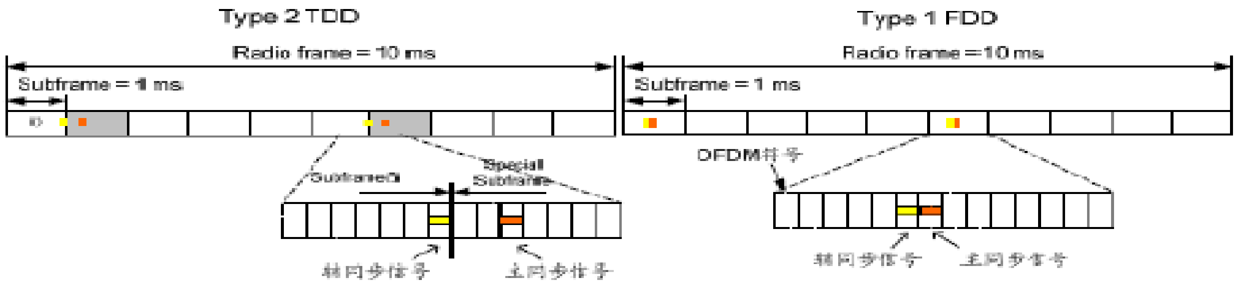
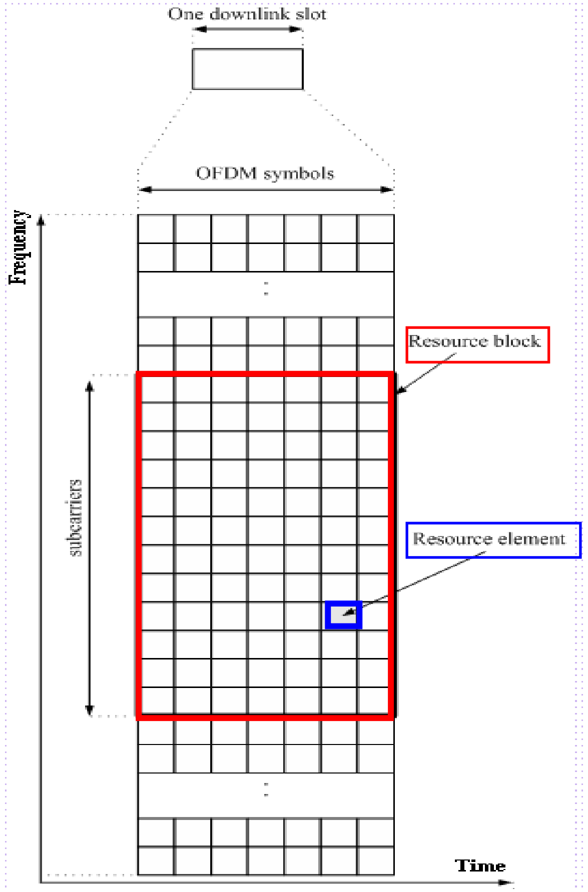


图5 TDD 帧结构同步信号设计

dential

Basic Concepts of LTE Resource Blocks

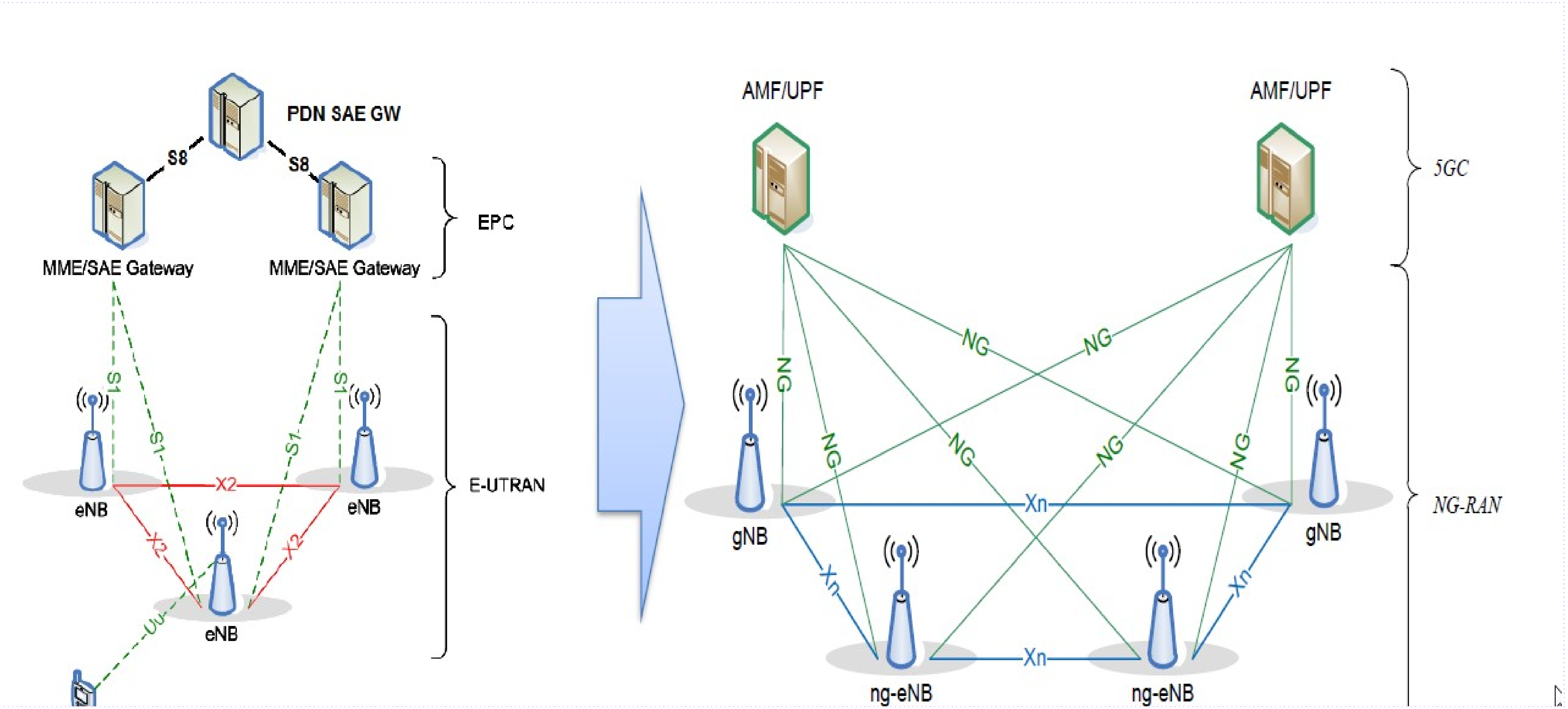
- **RE (Resource Element)**
  - Minimum granularity(element) of physical layer resources
  - Time domain 1 OFDM symbol frequency domain 1 subcarrier
- **RB Resource Block **
  - Minimum frequency domain unit of resource allocation for physical layer data transmission
  - Time domain 1 slot 12 consecutive Subcarriers
- **TTI**
  - Basic time-domain unit for data transmission scheduling at the physical layer1
  - TTI = 1 subframe = 2 slots
  - 1 TTI = 14 OFDM symbols (Normal CP)
  - 1 TTI = 12 OFDMsymbols (Extended CP)
- **CCE**
  - Control Channel Element
  - Resource unit of the control channel
  - 1 CCE = 36 REs
  - 1 CCE = 9 REGs (1 REG = 4 REs)



Carrier bandwidth [MHz]	RE numbers (each OFDM)	RB numbers each slot
1.4	72	6
3	180	15
5	300	25
10	600	50
15	900	75
20	1200	100

Contents

5G network architecture



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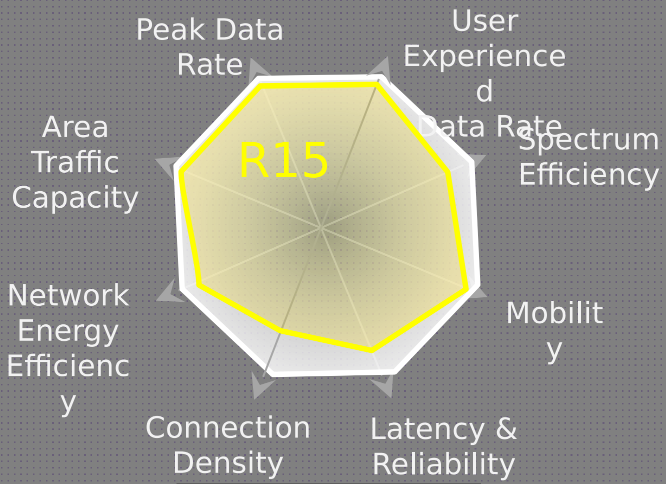
3GPP R15 focuses on eMBB, and R16 meets multiple service scenarios

Satisfy eMBB Universal Demands



eMBB

R15

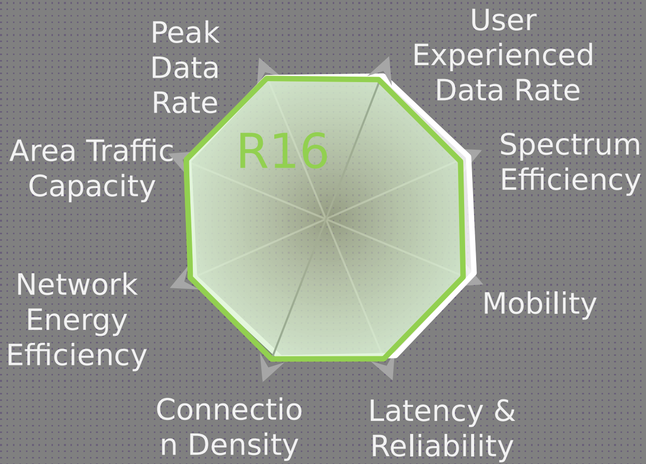
NR Framework
- Waveform & Channel Coding
- Frame Structure, Numerology
- Native MIMO
- Flexible Duplex

Spectrum
- 600MHz to 52.6GHz

Architecture
- UL&DL Decoupling
- CU-DU Split

Others: uRLLC

Focus on Diversified Requirements



eMBB + uRLLC + mMTC

R16

NR Improvement
- New Multiple Access
- eMBB Enhancement
- Self-Backhaul

Spectrum
- Up to 100GHz

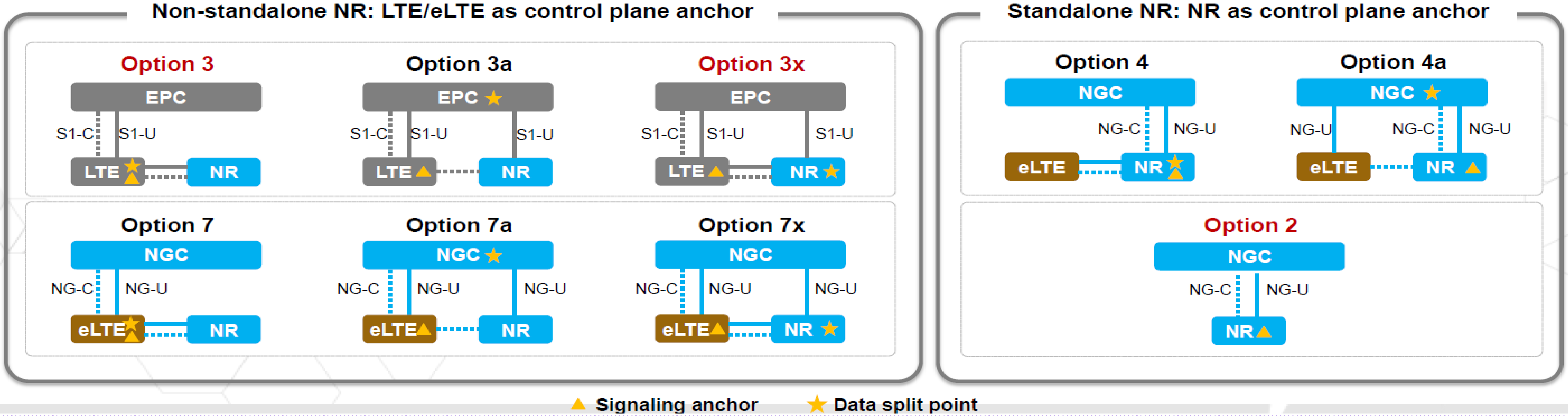
- **Vertical Digitalization**
- uRLLC
- mMTC

5G Networking Options

SA/NSA Definition (38.801)

Non-standalone NR: A deployment configuration where the gNB requires an LTE eNB as anchor for control plane connectivity to EPC, or an eLTE eNB as anchor for control plane connectivity to NGC.

Non-standalone E-UTRA: A deployment configuration where the eLTE eNB requires a gNB as anchor for control plane connectivity to NGC.



	Option 3x	Option 7x	Option 4	Option 2
LTE&NR DC	●	●	●	
LTE Upgrade	●	●	●	
5G Core Deployment		●	●	●
Service Readiness (eMBB/uRLLC/mMTC)		●	●	●

Option3x Preferred in NSA Option 2 Preferred in SA

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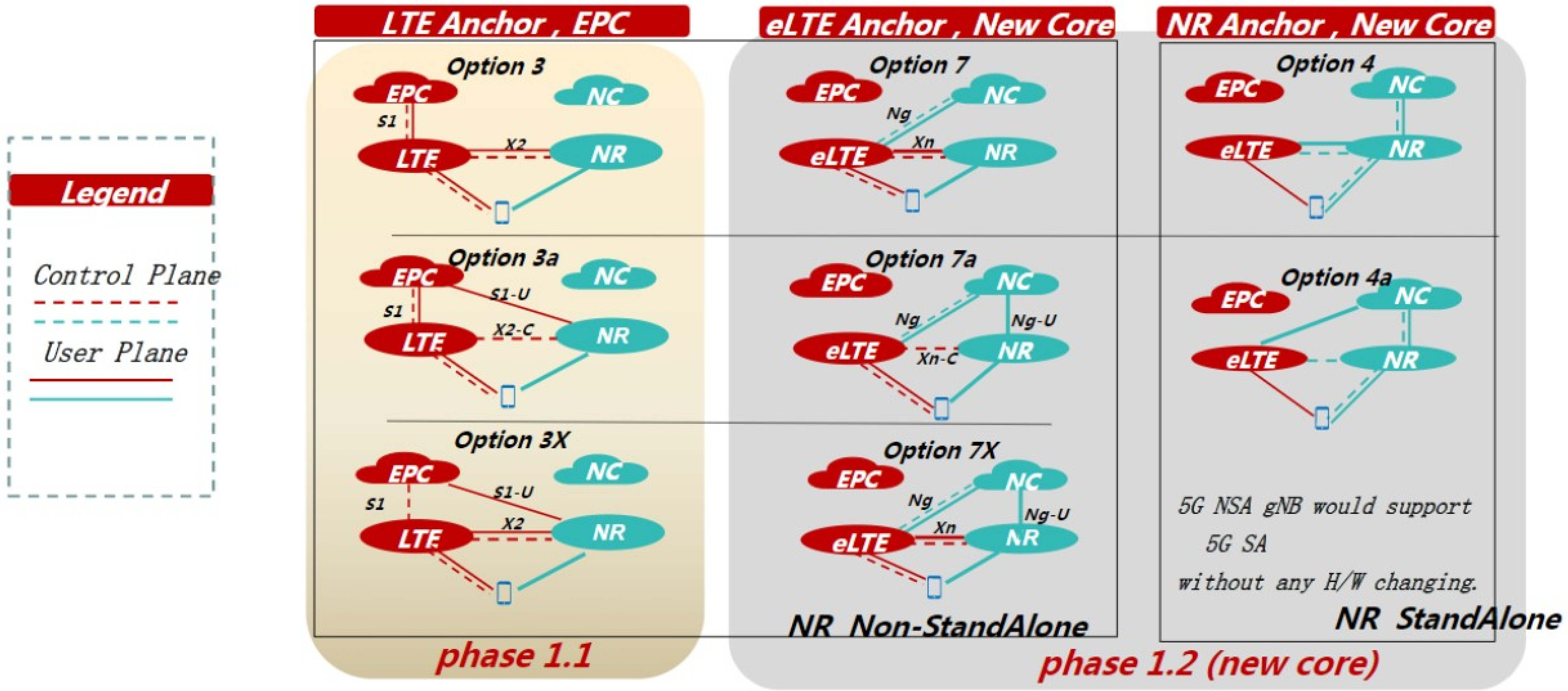
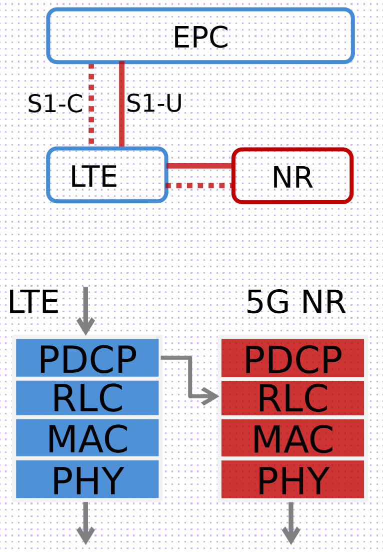
5G Networking Options



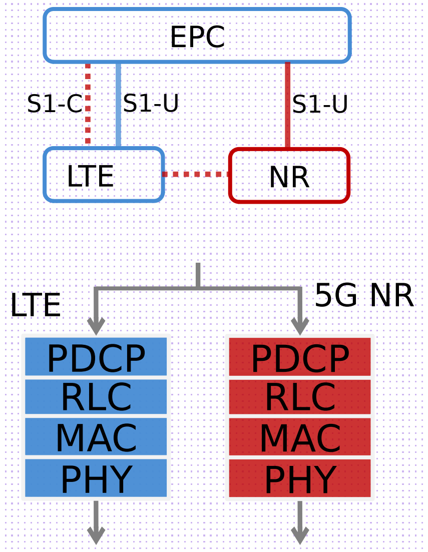
NSA Option3x Minimizes Impact on Existed LTE with Best Performance

Option 3



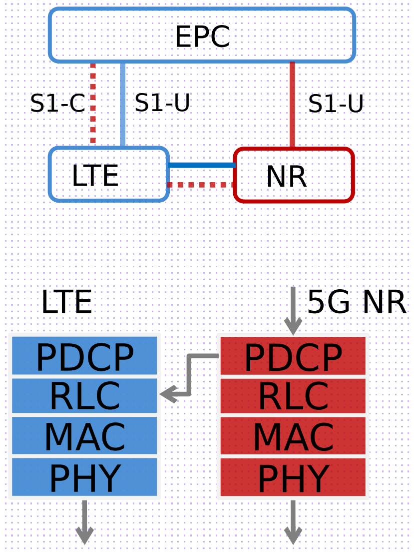
- Limited data peak rate
- Necessary LTE expansion for UP data split

Option3a



- Static UP data split without RAN status awareness

Option 3x



- Avoid impact to existed LTE for UP data split
- Dynamic UP data split in RAN at packet level provide better performance

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5G Spectrum defined by 3GPP(38104)

Sub6G

Table 5.2-1: NR operating bands in FR1

NR operating band	Uplink (UL) *operating band* BS receive / UE transmit F_{UL_low} – F_{UL_high}	Downlink (DL) *operating band* BS transmit / UE receive F_{DL_low} – F_{DL_high}	Duplex Mode
n1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	FDD
n2	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	FDD
n3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	FDD
n5	824 MHz – 849 MHz	869 MHz – 894 MHz	FDD
n7	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	FDD
n8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD
n12	699 MHz – 716 MHz	729 MHz – 746 MHz	FDD
n20	832 MHz – 862 MHz	791 MHz – 821 MHz	FDD
n25	1850 MHz – 1915 MHz	1930 MHz – 1995 MHz	FDD
n28	703 MHz – 748 MHz	758 MHz – 803 MHz	FDD
n34	2010 MHz – 2025 MHz	2010 MHz – 2025 MHz	TDD
n38	2570 MHz – 2620 MHz	2570 MHz – 2620 MHz	TDD
n39	1880 MHz – 1920 MHz	1880 MHz – 1920 MHz	TDD
n40	2300 MHz – 2400 MHz	2300 MHz – 2400 MHz	TDD
n41	2496 MHz – 2690 MHz	2496 MHz – 2690 MHz	TDD
n50	1432 MHz – 1517 MHz	1432 MHz – 1517 MHz	TDD[1]
n51	1427 MHz – 1432 MHz	1427 MHz – 1432 MHz	TDD
n66	1710 MHz – 1780 MHz	2110 MHz – 2200 MHz	FDD
n70	1695 MHz – 1710 MHz	1995 MHz – 2020 MHz	FDD
n71	663 MHz – 698 MHz	617 MHz – 652 MHz	FDD
n74	1427 MHz – 1470 MHz	1475 MHz – 1518 MHz	FDD
n75	N/A	1432 MHz – 1517 MHz	SDL
n76	N/A	1427 MHz – 1432 MHz	SDL
n77	3300 MHz – 4200 MHz	3300 MHz – 4200 MHz	TDD
n78	3300 MHz – 3800 MHz	3300 MHz – 3800 MHz	TDD
n79	4400 MHz – 5000 MHz	4400 MHz – 5000 MHz	TDD
n80	1710 MHz – 1785 MHz	N/A	SUL
n81	880 MHz – 915 MHz	N/A	SUL
n82	832 MHz – 862 MHz	N/A	SUL
n83	703 MHz – 748 MHz	N/A	SUL
n84	1920 MHz – 1980 MHz	N/A	SUL
n86	1710 MHz – 1780 MHz	N/A	SUL

SUL Supplementary Uplink Carrier , for UL&DL decoupling

mmWave

Table 5.2-2: NR *operating bands* in FR2

NR *operating band*	Uplink (UL) and Downlink (DL) *operating band* BS transmit/receive UE transmit/receive F_{UL_low} – F_{UL_high} F_{DL_low} – F_{DL_high}	Duplex Mode
n257	26500 MHz – 29500 MHz	TDD
n258	24250 MHz – 27500 MHz	TDD
n260	37000 MHz – 40000 MHz	TDD
n261	27500 MHz – 28350 MHz	TDD

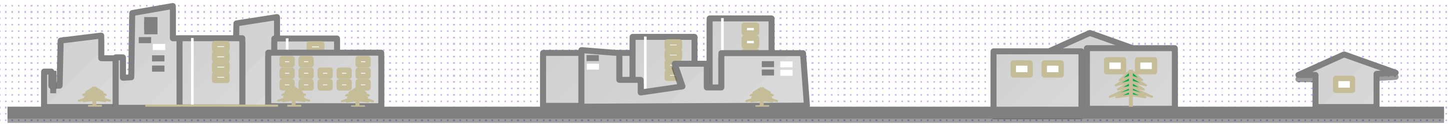
NR Bandwidth Supported by 3GPP

Frequency range 1:
< 6 GHz
- 5, 10,15, 20, 25, 30, 40, 50, 60, 80, 100 MHz

Frequency range 2:
> 24.25 GHz
- 50, 100, 200, 400 MHz

Spectrum distribution of 5G networks

Dense Urban | Urban | Suburban | Rural



mmWave(TDD) — **High Capacity**

C-Band (TDD) （3.3GHz — 4.9GHz） — **Good Capacity**

2.6GHz (T+F)

1.8GHz / 2.1GHz (FDD)

1400MHz (SDL)

700MHz/800MHz/900MHz (FDD)

Good Coverage

5G network will be multi-band network including Sub3G，C-band and mmWave

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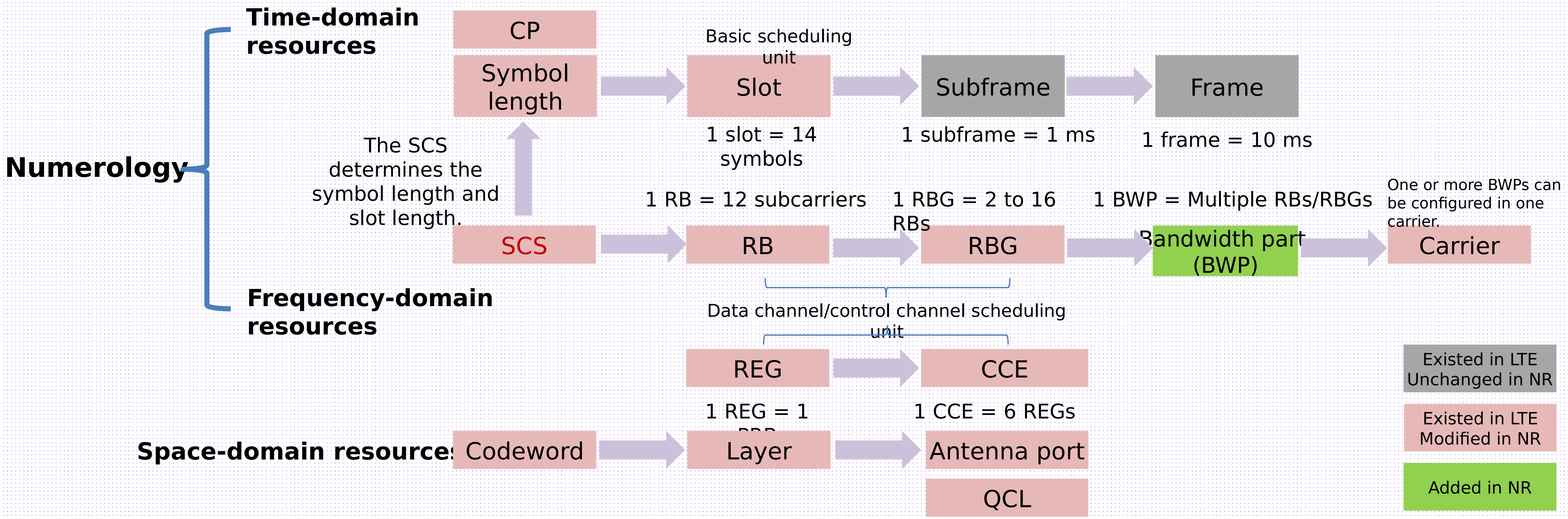
Contents

Overview of NR Air Interface Resources (Time-, Frequency-, and Space-domain Resources)

Numerology (system parameter): refers to subcarrier spacing (SCS) in New Radio (NR) and related parameters, such as the symbol length and cyclic prefix (CP) length.



NR uses orthogonal frequency division multiple access (OFDMA), same as LTE does.
The main description dimensions of air interface resources are similar between LTE and NR except that BWP is added to NR in the frequency domain.

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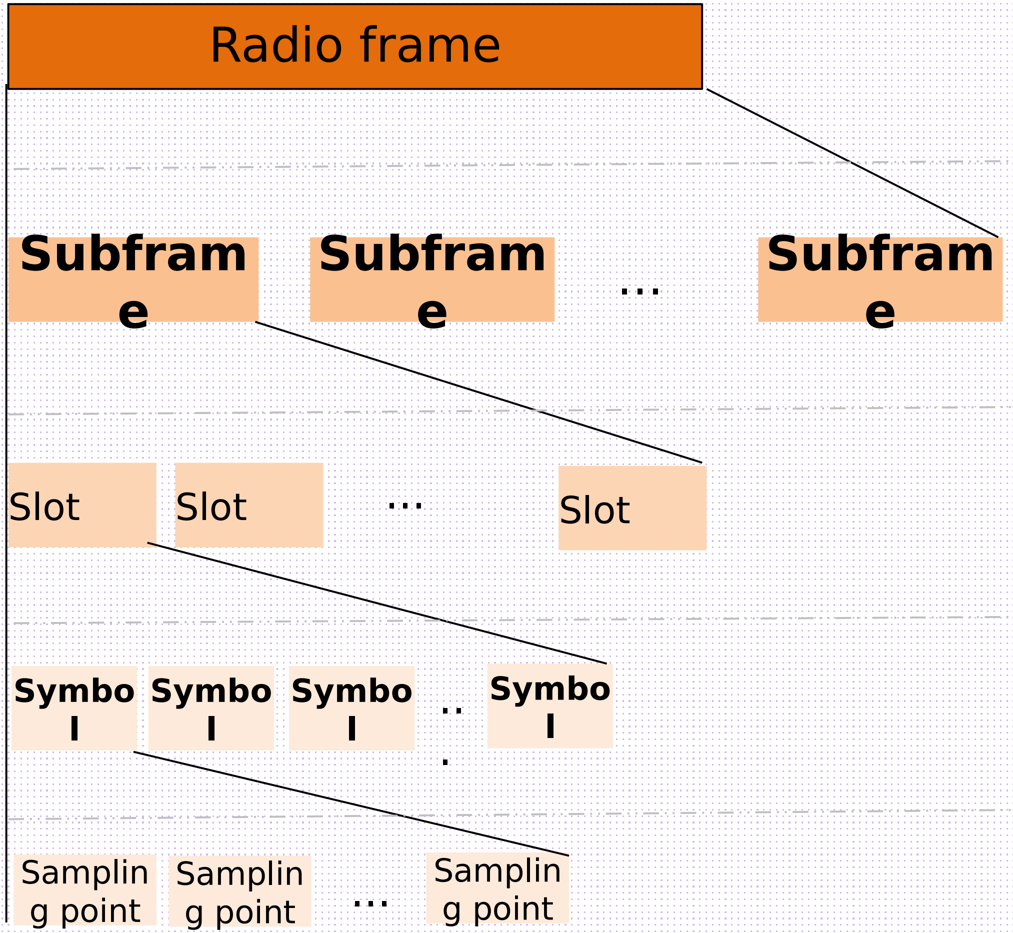
Time-domain Resources: Radio Frame, Subframe, Slot, Symbol



Inherited from LTE and has a fixed value of 10 ms

Inherited from LTE and has a fixed value of 1 ms

Minimum unit for data scheduling

Basic unit for modulation

Basic time unit at the physical layer

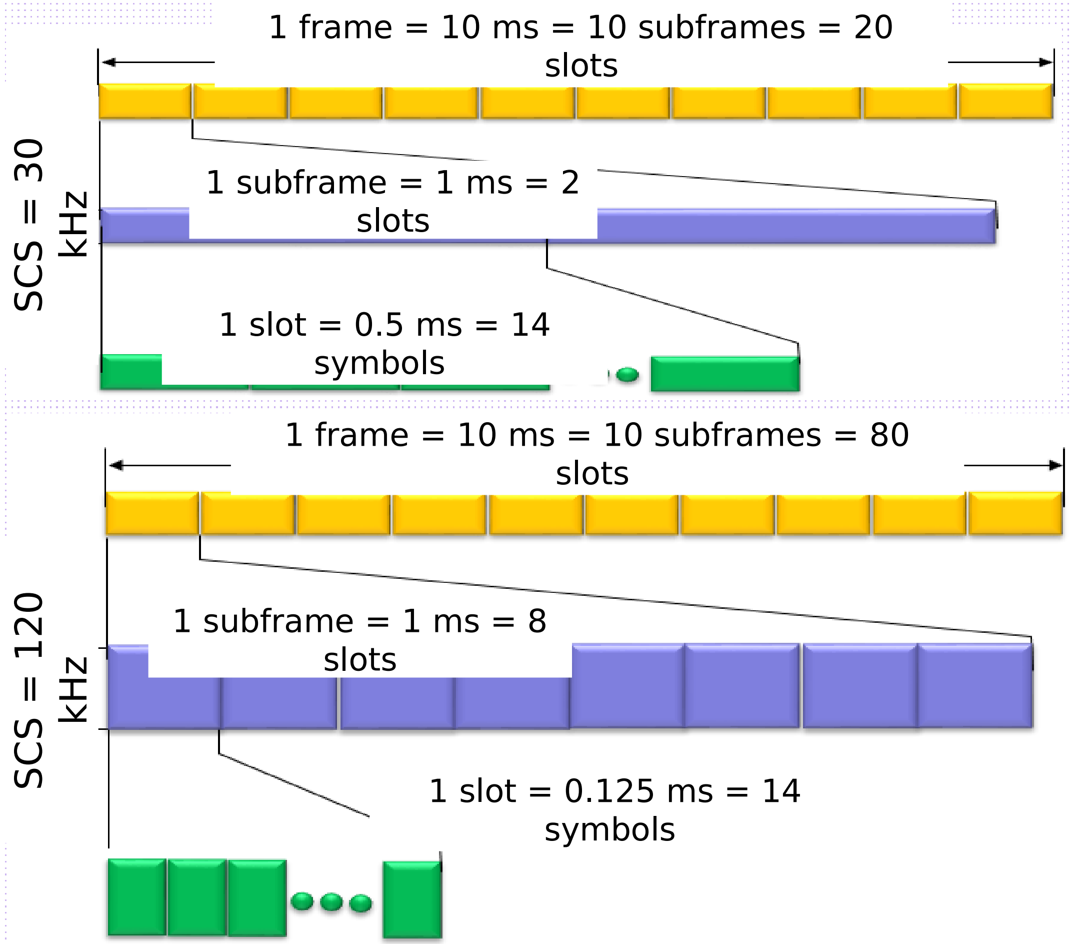
In the time domain, slot is a basic scheduling unit for data channels. The concepts of radio frames and subframes are the same as those in LTE.

Frame Structure: Architecture

- **Frame length: 10 ms**
  - SFN range: 0 to 1023
- **Subframe length: 1 ms**
  - Subframe index per system frame: 0 to 9
- **Slot length: 14 symbols**

SCS (kHz)	Slot Configuration (NCP)		
	Number of Symbols/Slot	Number of Slots/Subframe	Number of Slots /Frame
15	14	1	10
30	14	2	20
60	14	4	40
120	14	8	80
240	14	16	160
480	14	32	320
	Slot Configuration (ECP)		
60	12	4	40

- **Frame structure architecture:**
  - **Example: SCS = 30 kHz/120 kHz**



The lengths of a radio frame and a subframe in NR are consistent with those in LTE. The number of slots in each subframe is determined by the subcarrier width.

SCS–Background and Protocol-provided Definition

- **Background**
  - Service types supported by NR: eMBB, URLLC, mMTC, etc.
  - Frequency bands supported by NR: C-band, mmWave, etc.
  - Moving speed supported by NR: up to 500 km/h
- **Requirements for SCS vary with service types, frequency bands, and moving speeds.**
  - URLLC service (short latency): large SCS
  - Low frequency band (wide coverage): small SCS
  - High frequency band (large bandwidth, phase noise): large SCS
  - Ultra high speed mobility: large SCS
- **NR SCS design principle**
  - NR supports a series of SCS values A series of Scalable SCSs are obtained by extending the expansion

- **Numerologies defined in 3GPP Release 15 (TS 38.211) with SCS identified by the parameter μ**

Parameter μ	SCS	CP
0	15 kHz	Normal
1	30 kHz	Normal
2	60 kHz	Normal, extended
3	120 kHz	Normal
4	240 kHz	Normal

*(LTE supports only 15 kHz SCS.)

- **Available SCS for data channels and s**

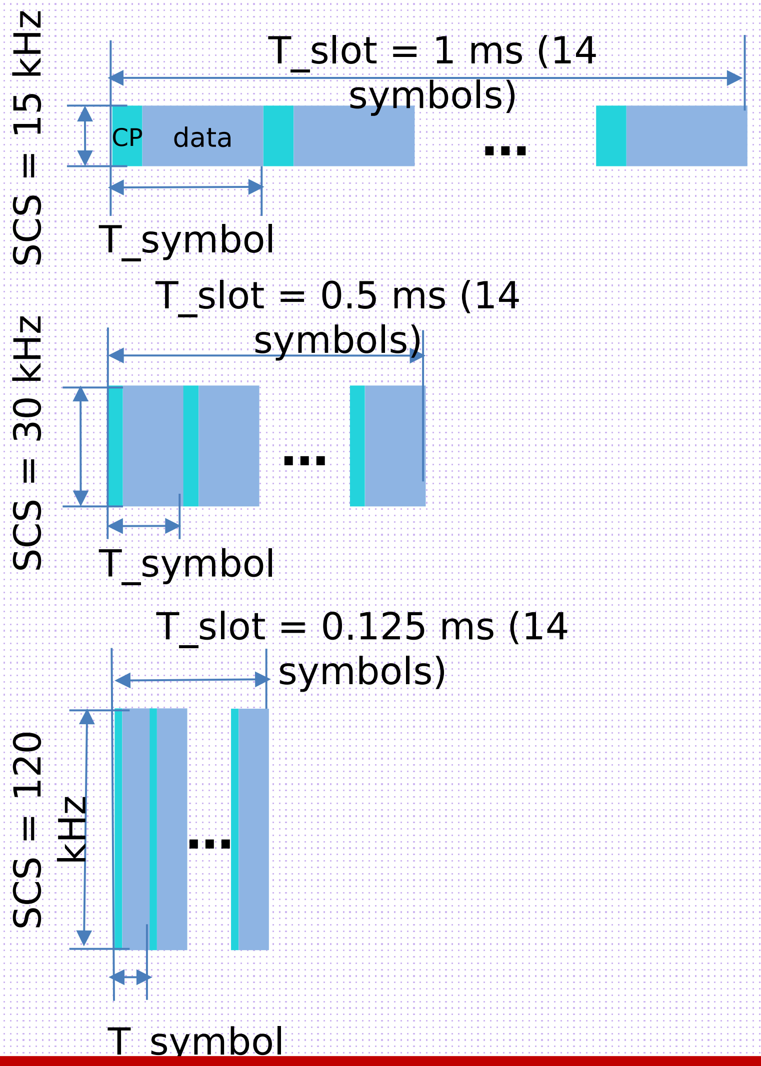
Parameter μ	SCS	Supported for Data (PDSCH, PUSCH etc)	Supported for Sync (PSS, SSS, PBCH)
0	15 kHz	Yes	Yes
1	30 kHz	Yes	Yes
2	60 kHz	Yes	No
3	120 kHz	Yes	Yes
4	240 kHz	No	Yes

Based on LTE SCS of 15 kHz, a series of numerologies (mainly different SC are supported to adapt to different requirements and channel characte

Symbol Length–Determined by SCS

- **Symbol = CP + Data**
- **SCS vs CP length/symbol length/slot length**
  - Length of OFDM symbols in data: **T_data = 1/SCS**
  - CP length: **T_cp = 144/2048 x T_data**
  - Symbol length (data+CP): **T_symbol = T_data +T_cp**
  - Slot length: **T_slot = 1 / 2^(μ)**

Parameter/Numerology (μ)	**0**	**1**	**2**	**3**	**4**
SCS (kHz): **SCS = 15 x 2^(μ)**	15	30	60	120	240
OFDM Symbol Duration (μs): **T_data = 1/SCS**	66.67	33.33	16.67	8.33	4.17
CP Duration (μs): **T_cp = 144/2048 x T_data**	4.69	2.34	1.17	0.59	0.29
OFDM Symbol Including CP (μs): **T_symbol = T_data + T_cp**	71.35	35.68	17.84	8.92	4.46
Slot Length (ms): **T_slot = 1/2^(μ)**	1	0.5	0.25	0.125	0.0625



A symbol consists of a CP and data. The length of the data is the reciprocal of SCS. The larger the SCS, the smaller the symbol length and the slot length.

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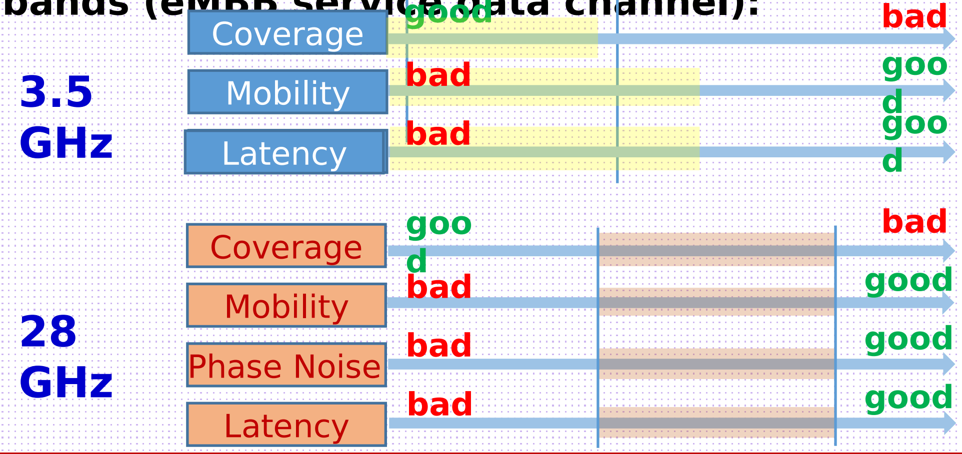
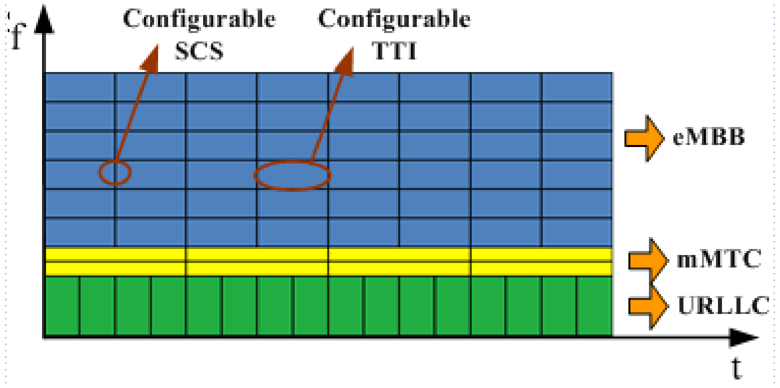
SCS: Application Scenarios and Suggestions

- **Impact of SCS on coverage, latency, mobility, and phase noise**
  - Coverage: The smaller the SCS, the longer the symbol length/CP, and the better the coverage.
  - Mobility: The larger the SCS, the smaller the impact of Doppler shift, and the better the performance.
  - Latency: The larger the SCS, the shorter the symbol length/latency.
  - Phase noise: The larger the SCS, the smaller the impact of phase noise, and the better the performance.
- **SCS app uency bands (eMBB service data channel):**

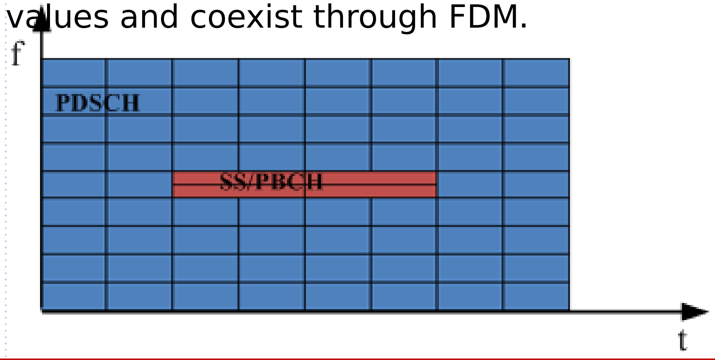
SCS (kHz)	15	30	60	120	240



- **Coexistence of different SCS values and FDM**
  - The eMBB and URLLC data channels use different



  - The PBCH and PDSCH/PUSCH use different SCS values and coexist through FDM.



It is recommended that the SCS be 30 kHz for C-band and 120 kHz for 28 GHz. Different SCS values and coexistence through FDM are supported.

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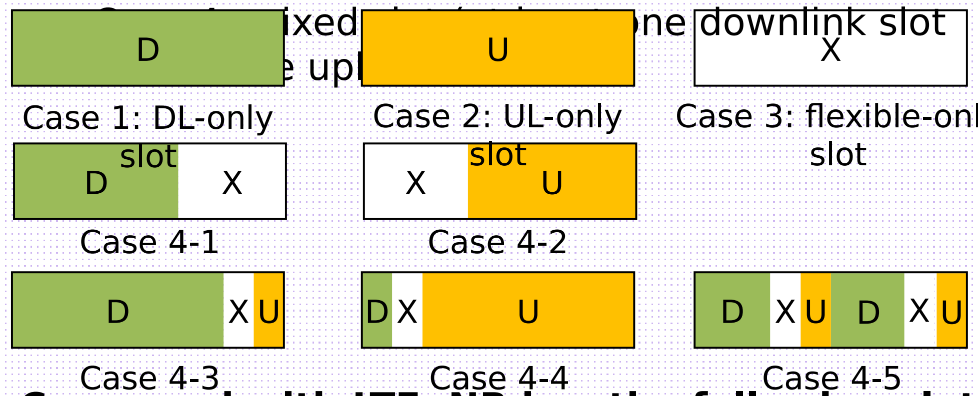
Slot Format and Type

- **Slot structure (section 4.3.2 of 3GPP TS 38.211)**
  - Downlink, denoted as D, for downlink transmission
  - Flexible, denoted as X, for uplink or downlink transmission, GP, or reserved.
  - Uplink, denoted as U, for uplink transmission
- **Main slot types**
  - Case 1: DL-only slot
  - Case 2: UL-only slot
  - Case 3: flexible-only slot
  - ...ixed ... ne downlink slot ... e upl...

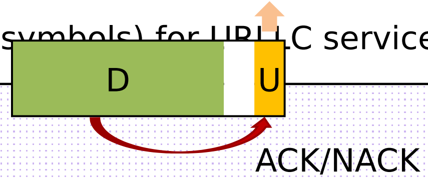


- **Compared with LTE, NR has the following slot format features:**
  - Flexibility: symbol-level uplink/downlink adaptation in NR and subframe-level in LTE
  - Diversity: More slots are supported in the NR system to cope with more scenarios and service types.

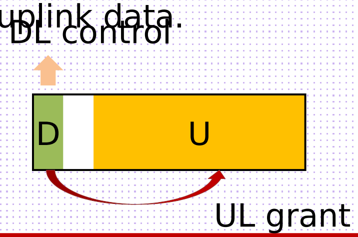
- **Examples of application scenarios of different slots:**

Slot Type	Application Scenario Example
Case 1	DL-heavy transmission
Case 2	UL-heavy transmission
Case 3	1. Forward compatibility: Resources are reserved for future services. 2. Adaptive adjustment of uplink and downlink resources: such as dynamic TDD
Case 4-1 Case 4-2	1. Forward compatibility: Resources are reserved for future services. 2. Flexible data transmission start and end locations: such as unlicensed frequency bands and dynamic TDD
Case 4-3	Downlink self-contained transmission
Case 4-4	Uplink self-contained transmission
Case 4-5	Mini-slot (seven symbols) for URLLC services

- One slot or subframe contains uplink part, downlink part, and GP.
- Downlink self-contained slot or subframe: includes downlink data and corresponding HARQ feedback.



- Uplink self-contained slot or subframe: includes uplink scheduling information and uplink data.



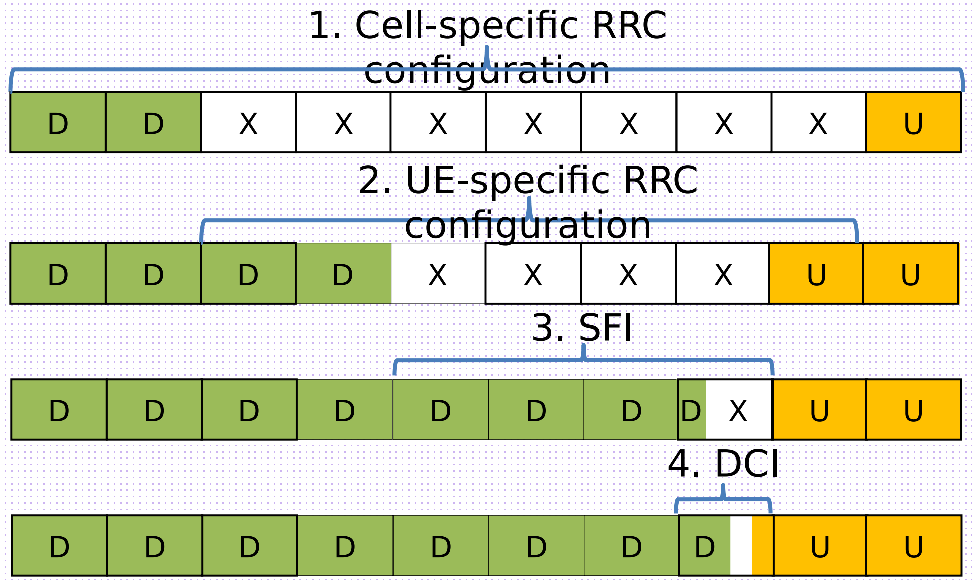
The number of uplink and downlink symbols in a slot can be flexibly configured. In Release 15, a mini-slot contains 2, 4, or 7 symbols for data scheduling in a short latency or a high frequency band scenario.

UL/DL Slot/Frame Configuration

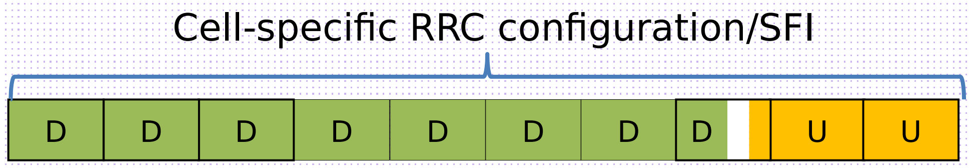
- **Configuration: in line with section 11.1 of 3GPP TS 38.213**
  - Layer 1: semi-static configuration through cell-specific RRC signaling
    - SIB1: *UL-DL-configuration-common* and *UL-DL-configuration-common-Set2*
    - Period: {0.5,0.625,1,1.25,2,2.5,5,10} ms, SCS dependent
  - Layer 2: semi-static configuration through UE-specific RRC signaling
    - Higher layer signaling: *UL-DL-configuration-dedicated*
    - Period: {0.5,0.625,1,1.25,2,2.5,5,10} ms, SCS dependent
  - Layer 3: dynamic configuration through UE-group SFI
    - DCI format 2_0
    - Period: {1,2,4,5,8,10,20} slots, SCS dependent
  - Layer 4: dynamic configuration through UE-specific DCI
    - DCI format 0, 1
- **Main characteristics: hierarchical configuration or separate configuration of each layer**
  - Different from LTE, the NR system supports UE-specific configuration, which delivers high flexibility.
  - Support for symbol-level dynamic TDD

- **Hierarchical configuration**

If X slots/symbols are configured at the upper layer, D or U slots/symbols are also configured at the lower layer.



- **Separate layer configuration**



Frame configuration supports hierarchical configuration through RRC signaling and DCI to deliver symbol-level dynamic TDD and high flexibility.

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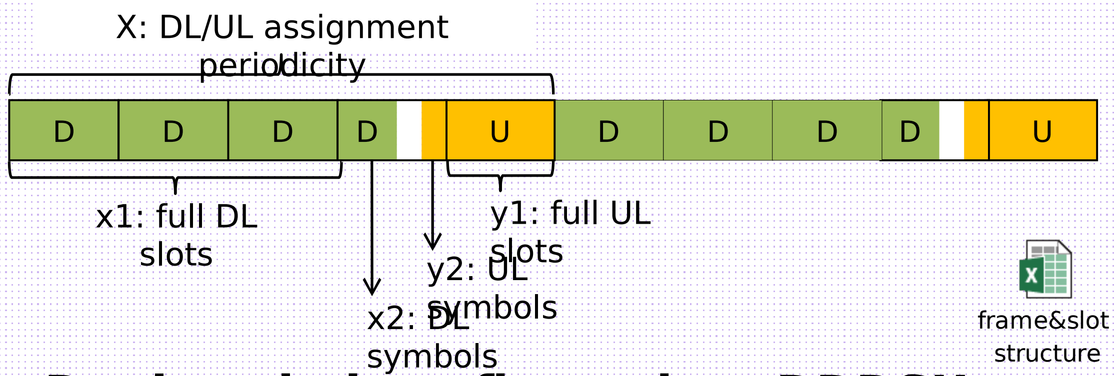
UL/DL Slot/Frame Configuration: Cell-specific Semi-static Configuration

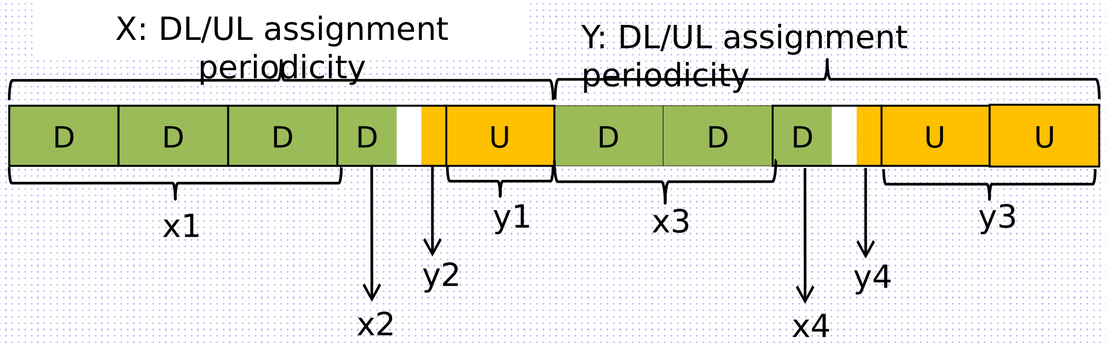
- **Cell-specific RRC signaling parameters**
  - Parameter: SIB1
    - *UL-DL-configuration-common: {X, x1, x2, y1, y2}*
    - *UL-DL-configuration-common-Set2*: *{Y, x3, x4, y3, y4}*
  - X/Y: assignment period
    - {0.5, 0.625, 1, 1.25, 2, 2.5, 5, 10} ms
    - 0.625 ms is used only when the SCS is 120 kHz. 1.25 ms is used when the SCS is 60 kHz or larger. 2.5 ms is used when the SCS is 30 kHz or larger.
    - A single period or two periods can be configured.
  - x1/x3: number of downlink-only slots
    - {0,1,..., number of slots in the assignment period}
  - y1/y3: number of uplink-only slots
    - {0,1,..., number of slots in the assignment period}
  - x2/x4: number of downlink symbols following downlink-only slots
    - {0,1,...,13}
  - y2/y4: number of uplink symbols followed by uplink-only slots
    - {0,1,...,13}

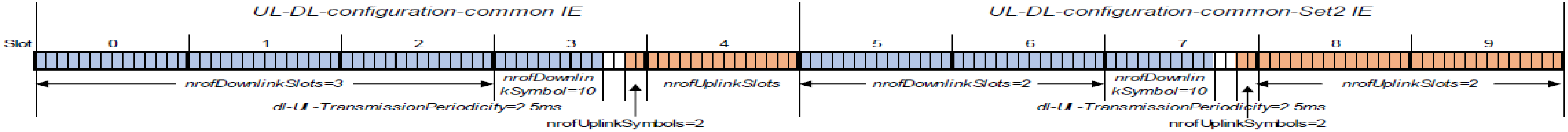
- **Single-period configuration: DDDSU**



frame&slot structure

- **Dual-period configuration: DDDSU DDSUU**

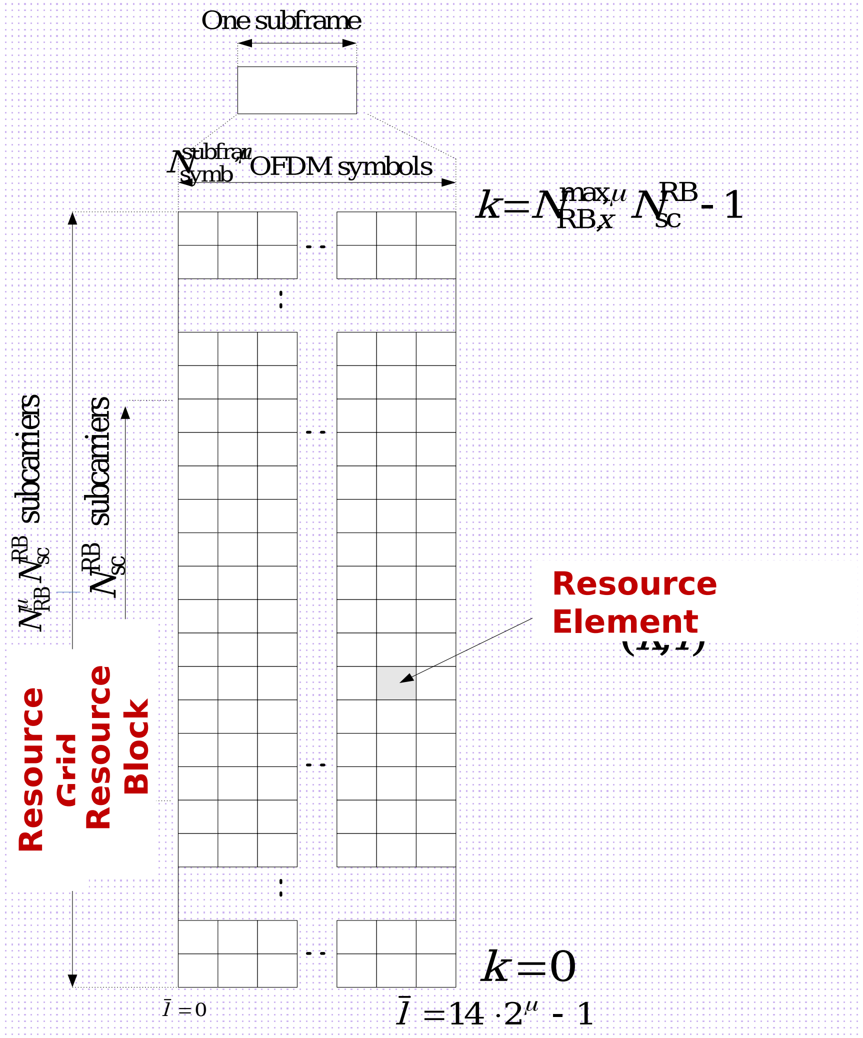




Cell-specific semi-persistent configuration supports limited configuration period options, and flexible static configuration of DL/UL resources are realized through RRC signaling.

Basic Concepts of Frequency-Domain Resources

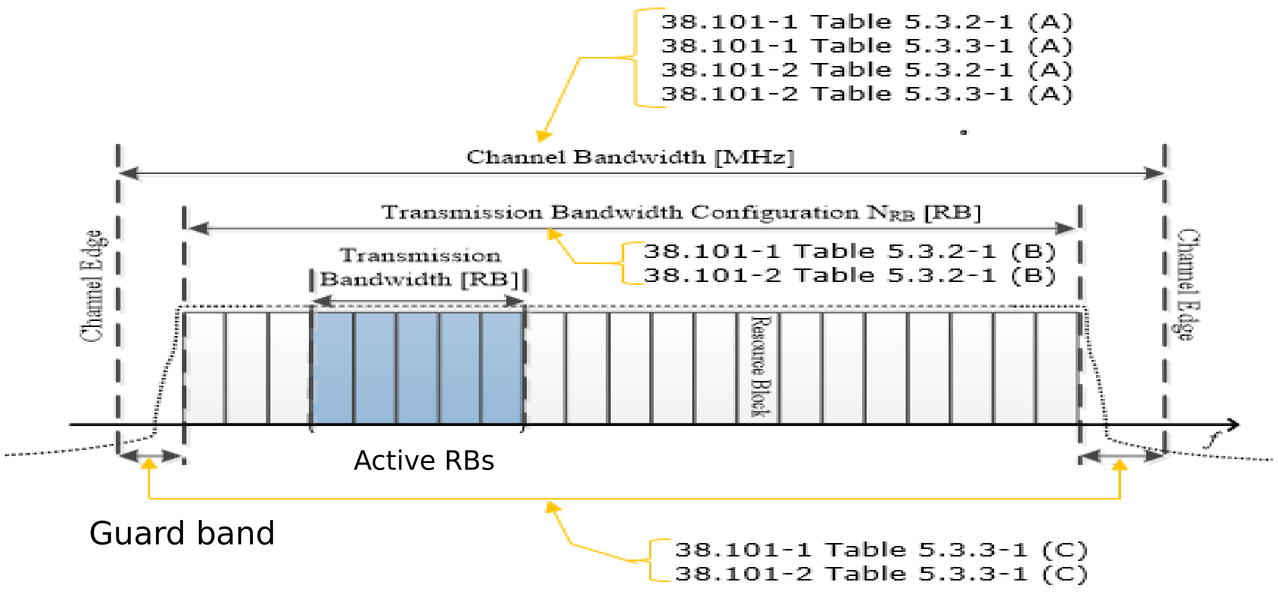
- **Resource Grid (RG)**
  - Physical-layer resource group, which is defined separately for the uplink and downlink (RGs are defined for each numerology).
  - Frequency domain: available RB resources within the transmission bandwidth
  - Time domain: 1 subframe
- **Resource Block (RB)**
  - Basic scheduling unit for data channel resource allocation in the frequency domain
  - Frequency domain: 12 consecutive subcarriers
- **Resource Element (RE)**
  - Minimum granularity of physical-layer resources
  - Frequency domain: 1 subcarrier
  - Time domain: 1 OFDM symbol



In NR, an RB corresponds to 12 subcarriers (same as LTE) in the frequency domain. The frequency-domain width is related to SCS and is calculated using 2^{μ} x 180 kHz.

Channel Bandwidth and Transmission Bandwidth

- **Channel bandwidth**
  - Channel bandwidth supported by the FR1 frequency band (450 MHz to 6000 MHz): 5 MHz (minimum), 100 MHz (maximum)
  - Channel bandwidth supported by the FR2 frequency band (24 GHz to 52 GHz): 50 MHz (minimum), 400 MHz (maximum).
- **Maximum transmission bandwidth (maximum number of available RBs)**
  - Determined by the channel bandwidth and data channel SCS.
  - Defined on the gNodeB side and UE side separately. For details about the protocol-configuration of the UE side, see the figure on the right.
- **Guard bandwidth**
  - With F-OFDM, the guard bandwidth decreases to about 2% in NR (corresponding to 30 kHz SCS, 100 MHz channel bandwidth).



- **Minimum guard bandwidth in various system bandwidth configurations**

SCS (kHz)	5 MHz	10 MHz	15 MHz	20 MHz	25 MHz	30 MHz	40 MHz	50MHz	60 MHz	80 MHz	100 MHz
15	242.5	312.5	382.5	452.5	522.5	[592.5]	552.5	692.5	N/A	N/A	N/A
30	505	665	645	805	785	[945]	905	1045	825	925	845
60	N/A	1010	990	1330	1310	[1290]	1610	1570	1530	1450	1370

Compared with the guard bandwidth (10%) in LTE, NR uses F-OFDM to reduce the guard bandwidth to about 2%.

Maximum Number of Available RBs and Spectrum Utilization

- **Spectrum utilization = Maximum transmission bandwidth/Channel bandwidth**
  - Maximum transmission bandwidth on the gNodeB side: See Table 5.3.2-1 and 5.3.2-2 in 3GPP TS 38.104.

SCS [kHz]	5 MHz	10 MHz	15 MHz	30 MHz	20 MHz	25 MHz	40 MHz	50 MHz	60 MHz	70 MHz	80 MHz	90 MHz	100 MHz
	N_{RB} and Spectrum Utilization (FR1:400 MHz to 6000 MHz)												
15	25	52	79	[160]	106	133	216	270	N/A	N/A	N/A	N/A	N/A
	90%	93.6%	94.8%	[96%]	95.4%	95.8%	97.2%	97.2%	\	\	\	\	\
30	11	24	38	[78]	51	65	106	133	162	[189]	217	[245]	273
	79.2%	86.4%	91.2%		91.8%	93.6%	95.4%	95.8%	97.2%		97.7%		98.3%
60	N/A	11	18	[38]	24	31	51	65	79	[93]	107	[121]	135
		79.2%	86.4%		86.4%	893%	91.8%	93.6%	94.8%		93.6%		97.2%

SCS [kHz]	50 MHz	100 MHz	200 MHz	400 MHz
	N_{RB} and Spectrum Utilization (FR2: 24 GHz to 52 GHz)			
60	66	132	264	N/A
	95%	95%	95%	\
120	32	66	132	264
	92.2%	95%	95%	95%

Spectrum utilization is related to the channel bandwidth. The higher the bandwidth, the higher the spectral efficiency.

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Question after course

- NR bandwidth 100Mhz, scs=60khz, how many RBS in the RG ? how calculate?
- NR bandwidth 100Mhz , scs=30khz , NR radio frame is DDDSU with single period , slot structure is SS2, Number of scheduling times per second? And if the radio frame is double period with DDDSUDDSUU   SS2, the result?
- NR bandwidth 100Mhz , scs=30khz ,NR radio frame is single period DDDDDDDSUU, slot structure is SS2, Number of scheduling times per second? If the slot structure is SS56,what about the result ？
- NR bandwidth 20Mhz , scs=15khz , NR radio frame is DDDSU with single period , slot structure is SS2, Number of scheduling times per second? And if the radio frame is double period with DDDSUDDSUU   SS2, the result?
- THE reason for longer SCS is better for Urllc&high speed, shorter SCS for MMTC?

Extension Questions

- LTE TDD radio frame is DDDSU with single period , special subframe structure is 3:9:2, Number of scheduling times per second ? If special subframe structure is 9:3:2, what about the result?

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Thank You

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